Ambient Light Derived by Subsampling Video Content and Mapped Through Unrendered Color Space

This invention relates to production and setting of ambient lighting effects using
5   multiple light sources, and typically based on, or associated with, video content, such as from
a video display. More particularly, it relates to a method to drive or set multiple ambient light
sources by extracting selected color information from subsampled video in real time, and
performing color mapping transformations from the video environment to that which allows
driving a plurality of ambient light sources.

10   Engineers have long sought to broaden the sensory experience obtained consuming
video content, such as by enlarging viewing screens and projection areas, modulating sound
for realistic 3-dimensional effects, and enhancing video images, including broader video color
gamuts, resolution, and picture aspect ratios, such as with high definition (HD) digital TV
television and video systems. Moreover, film, TV, and video producers also try to influence

15   the experience of the viewer using visual and auditory means, such as by clever use of color,
scene cuts, viewing angles, peripheral scenery, and computer-assisted graphical
representations. This would include theatrical stage lighting as well. Lighting effects, for
example, are usually scripted – synchronized with video or play scenes – and reproduced with
the aid of a machine or computer programmed with the appropriate scene scripts encoded with

20   the desired schemes.

In the prior art digital domain, automatic adaptation of lighting to fast changes in a
scene, including unplanned or unscripted scenes, has not been easy to orchestrate in large part
because of the overhead of large high bandwidth bit streams required using present systems.

Philips (Netherlands) and other companies have disclosed means for changing
25   ambient or peripheral lighting to enhance video content for typical home or business
applications, using separate light sources far from the video display, and for many
applications, some sort of advance scripting or encoding of the desired lighting effects.

Ambient lighting added to a video display or television has been shown to reduce viewer fatigue and improve realism and depth of experience.

Sensory experiences are naturally a function of aspects of human vision, which uses an enormously complex sensory and neural apparatus to produce sensations of color and light
5   effects. Humans can distinguish perhaps 10 million distinct colors. In the human eye, for color-receiving or photopic vision, there are three sets of approximately 2 million sensory bodies called cones which have absorption distributions which peak at 445, 535, and 565 nm light wavelengths, with a great deal of overlap. These three cone types form what is called a tristimulus system and are called B (blue), G (green), and R (red) for historical reasons; the
10   peaks do not necessarily correspond with those of any primary colors used in a display, e.g., commonly used RGB phosphors. There is also interaction for scotopic, or so-called night vision bodies called rods. The human eye typically has 120 million rods, which influence video experiences, especially for low light conditions such as found in a home theatre.

Color video is founded upon the principles of human vision, and well known
15   trichromatic and opponent channel theories of human vision have been incorporated into our understanding of how to influence the eye to see desired colors and effects which have high fidelity to an original or intended image. In most color models and spaces, three dimensions or coordinates are used to describe human visual experience.

Color video relies absolutely on metamerism, which allows production of color
20   perception using a small number of reference stimuli, rather than actual light of the desired color and character. In this way, a whole gamut of colors is reproduced in the human mind using a limited number of reference stimuli, such as well known RGB (red, green, blue) tristimulus systems used in video reproduction worldwide. It is well known, for example, that nearly all video displays show yellow scene light by producing approximately equal amounts
25   of red and green light in each pixel or picture element. The pixels are small in relation to the solid angle they subtend, and the eye is fooled into perceiving yellow; it does not perceive the green or red that is actually being broadcast.

There exist many color models and ways of specifying colors, including well

known CIE (Commission Internationale de l'Eclairage) color coordinate systems in use to describe and specify color for video reproduction. Any number of color models can be employed using the instant invention, including application to unrendered opponent color spaces, such as the CIE L*U*V* (CIELUV) or CIE L*a*b* (CIELAB) systems. The CIE

5   established in 1931 a foundation for all color management and reproduction, and the result is a chromaticity diagram which uses three coordinates, x, y, and z. A plot of this three dimensional system at maximum luminosity is universally used to describe color in terms of x and y, and this plot, called the 1931 x,y chromaticity diagram, is believed to be able to describe all perceived color in humans. This is in contrast to color reproduction, where

10   metamerism is used to fool the eye and brain. Many color models or spaces are in use today for reproducing color by using three primary colors or phosphors, among them Adobe RGB, NTSC RGB, etc.

It is important to note, however, that the range of all possible colors exhibited by video systems using these tristimulus systems is limited. The NTSC (National Television

15   Standards Committee) RGB system has a relatively wide range of colors available, but this system can only reproduce half of all colors perceivable by humans. Many blues and violets, blue-greens, and oranges/reds are not rendered adequately using the available scope of traditional video systems.

Furthermore, the human visual system is endowed with qualities of compensation

20   and discernment whose understanding is necessary to design any video system. Color in humans can occur in several modes of appearance, among them, object mode and illuminant mode.

In object mode, the light stimulus is perceived as light reflected from an object illuminated by a light source. In illuminant mode, the light stimulus is seen as a source of

25   light. Illuminant mode includes stimuli in a complex field that are much brighter than other stimuli. It does not include stimuli known to be light sources, such as video displays, whose brightness or luminance is at or below the overall brightness of the scene or field of view so that the stimuli appear to be in object mode.

Remarkably, there are many colors which appear only in object mode, among them,

30   brown, olive, maroon, grey, and beige flesh tone. There is no such thing, for example, as a

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brown illuminant source of light, such as a brown-colored traffic light.

For this reason, ambient lighting supplements to video systems which attempt to add object colors cannot do so using direct sources of bright light. No combination of bright red and green sources of light at close range can reproduce brown or maroon, and this limits

5   choices considerably. Only spectral colors of the rainbow, in varying intensities and saturation, can be reproduced by direct observation of bright sources of light. This underscores the need for fine control over ambient lighting systems, such as to provide low intensity luminance output from light sources with particular attention to hue management. This fine control is not presently addressed in a way that permits fast-changing and subtle

10   ambient lighting under present data architectures.

Video reproduction can take many forms. Spectral color reproduction allows exact reproduction of the spectral power distributions of the original stimuli, but this is not realizable in any video reproduction that uses three primaries. Exact color reproduction can replicate human visual tristimulus values, creating a metameric match to the original, but overall

15   viewing conditions for the picture and the original scene must be similar to obtain a similar appearance. Overall conditions for the picture and original scene include the angular subtense of the picture, the luminance and chromaticity of the surround, and glare. One reason that exact color reproduction often cannot be achieved is because of limitations on the maximum luminance that can be produced on a color monitor.

20   Colorimetric color reproduction provides a useful alternative where tristimulus values are proportional to those in the original scene. Chromaticity coordinates are reproduced exactly, but with proportionally reduced luminances. Colorimetric color reproduction is a good reference standard for video systems, assuming that the original and the reproduced reference whites have the same chromaticity, the viewing conditions are the same,

25   and the system has an overall gamma of unity. Equivalent color reproduction, where chromaticity and luminances match the original scene cannot be achieved because of the limited luminance generated in video displays.

Most video reproduction in practice attempts to achieve corresponding color reproduction, where colors reproduced have the same appearance that colors in the original

30   would have had if they had been illuminated to produce the same average luminance level and

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the same reference white chromaticity as that of the reproduction. Many, however, argue that the ultimate aim for display systems is in practice preferred color reproduction, where preferences of the viewer influence color fidelity. For example, suntanned skin color is preferred to average real skin color, and sky is preferred bluer and foliage greener than they

5   really are. Even if corresponding color reproduction is accepted as a design standard, some colors are more important than others, such as flesh tones, the subject of special treatment in many reproduction systems such as the NTSC video standard.

In reproducing scene light, chromatic adaptation to achieve white balance is important. With properly adjusted cameras and displays, whites and neutral grays are

10 typically reproduced with the chromaticity of CIE standard daylight illuminant D65. By always reproducing a white surface with the same chromaticity, the system is mimicking the human visual system, which inherently adapts perceptions so that white surfaces always appear the same, whatever the chromaticity of the illuminant, so that a white piece of paper will appear white, whether it is found in a bright sunlight day at the beach, or a incandescent-

15 lit indoor scene. In color reproduction, white balance adjustment usually is made by gain controls on the R, G, and B channels.

The light output of a typical color receiver is typically not linear, but rather follows a power-law relationship to applied video voltages. The light output is proportional to the video-driving voltage raised to the power gamma, where gamma is typically 2.5 for a color

20 CRT (cathode ray tube), and 1.8 for other types of light sources. Compensation for this factor is made via three primary gamma correctors in camera video processing amplifiers, so that the primary video signals that are encoded, transmitted and decoded are in fact not R, G, and B, but $R^{1/(}$, $G^{1/(}$, and $B^{1/(}$. Colorimetric color reproduction requires that the overall gamma for video reproduction – including camera, display, and any gamma-adjusting electronics be

25 unity, but when corresponding color reproduction is attempted, the luminance of the surround take precedence. For example, a dim surround requires a gamma of about 1.2, and a dark surround requires a gamma of about 1.5 for optimum color reproduction. Gamma is an important implementation issue for RGB color spaces.

Most color reproduction encoding uses standard RGB color spaces, such as sRGB,

ROMM RGB, Adobe RGB 98, Apple RGB, and video RGB spaces such as that used in the
NTSC standard. Typically, an image is captured into a sensor or source device space, which is
device and image specific. It may be transformed into an unrendered image space, which is a
standard color space describing the original's colorimetry (see Definitions section).

5   However, video images are nearly always directly transformed from a source device
space into a rendered image space (see Definitions section), which describes the color space of
some real or virtual output device such as a video display. Most existing standard RGB color
spaces are rendered image spaces. For example, source and output spaces created by cameras
and scanners are not CIE-based color spaces, but spectral spaces defined by spectral
10   sensitivities and other characteristics of the camera or scanner.

Rendered image spaces are device-specific color spaces based on the colorimetry of
real or virtual device characteristics. Images can be transformed into rendered spaces from
either rendered or unrendered image spaces. The complexity of these transforms varies, and
can include complicated image dependent algorithms. The transforms can be non-reversible,
15   with some information of the original scene encoding discarded or compressed to fit the
dynamic range and gamut of a specific device.

There is currently only one unrendered RGB color space that is in the process of
becoming a standard, ISO RGB defined in ISO 17321, most often used for color
characterization of digital still cameras. In most applications today, images are converted into
20   a rendered color space for either archiving and data transfer, including video signals.
Converting from one rendered image or color space to another can cause cause severe image
artifacts. The more mismatched the gamuts and white points are between two devices, the
stronger the negative effects.

One problem in prior art ambient light display systems is that no specific method is
25   given to provide for synchronous real time operation to transform rendered tristimulus values
from video to that of ambient light sources to give proper colorimetry and appearance. For
example, output from LED ambient light sources is often garish, with limited or skewed color
gamuts, and hue and chroma are difficult to assess and reproduce. For example, US Patent
6,611,297 to Akashi et al. deals with realism in ambient lighting, but no specific method is
30   given to insure correct and pleasing chromaticity, and the teaching of Akashi '297 does not

allow for analyzing video in real time, but rather needs a script or the equivalent.

In addition, setting of ambient light sources using gamma corrected color spaces from video content often result in garish, bright colors. A more serious problem in the prior art is the large amount of transmitted information that is needed to drive ambient light sources as a function of real time video content, and to suit a desired fast-changing ambient light environment where good color matching is desired.

It is therefore advantageous to expand the possible gamut of colors produced by ambient lighting in conjunction with a typical tristimulus video display system. It is also desired to exploit characteristics of the human eye, such as changes in relative luminosity of different colors as a function of light levels, by modulating or changing color and light character delivered to the video user using an ambient lighting system that uses to good advantage compensating effects, sensitivities, and other peculiarities of human vision.

It is also advantageous to create a quality ambient atmosphere free from the effects of gamma-induced distortion. It is further desired to be able to provide a method for providing emulative ambient lighting drawn from selected video regions using an economical data stream that encodes average or characterized color values. It is yet further desired to reduce the required size of such a datastream further.

Information about video and television engineering, compression technologies, data transfer and encoding, human vision, color science and perception, color spaces, colorimetry and image rendering, including video reproduction, can be found in the following references which are hereby incorporated into this disclosure in their entirety: ref[1] Color Perception, Alan R. Robertson, Physics Today, December 1992, Vol 45, No 12, pp. 24-29; ref[2] The Physics and Chemistry of Color, 2ed, Kurt Nassau, John Wiley & Sons, Inc., New York © 2001; ref[3] Principles of Color Technology, 3ed, Roy S. Berns, John Wiley & Sons, Inc., New York, © 2000; ref[4] Standard Handbook of Video and Television Engineering, 4ed, Jerry Whitaker and K. Blair Benson, McGraw-Hill, New York © 2003.

The invention relates to a method for extracting and processing video content encoded in a rendered color space to be emulated by an ambient light source, and using an interframe interpolation process, comprising [1] Extracting color information from a video signal that encodes at least some of said video content in said rendered color space by

decoding said video signal into a set of frames, extracting said color information from only selected extraction frames, and performing interframe interpolation between said extraction frames to yield interpolated frames, said color information then newly derived from said extraction frames and said interpolated frames; [2] Transforming the color information to an
5   unrendered color space; [3] Transforming the color information from the unrendered color space to a second rendered color space so formed as to allow driving the ambient light source.

Step [1] can additionally comprise decoding the video signal into a set of frames; extracting an average color from the color information, including at least one extraction of the color information from an extraction region; using the extraction of the color information to
10   broadcast ambient light from the ambient light source adjacent the extraction region. In addition, one can perform a gamma correction to the second rendered color space fed to the ambient light units.

Steps [2] and [3] can additionally comprise matrix transformations of primaries of the rendered color space and second rendered color space to the unrendered color space using
15   first and second tristimulus primary matrices;and deriving a transformation of the color information into the second rendered color space by matrix multiplication of the primaries of the rendered color space, the first tristimulus matrix, and the inverse of the second tristimulus matrix.

The unrendered color space can be one of CIE XYZ; ISO RGB defined in ISO
20   Standard 17321; Photo YCC; and CIE LAB, and steps [1], [2], and [3] can be substantially synchronous with the video signal, with ambient light broadcast from or around the video display using the color information in the second rendered color space.

Another method is disclosed for extracting and processing border region video content from a rendered color space to be emulated by an ambient light source and using an
25   interframe interpolation process, comprising:

[1] Extracting color information from a video signal that encodes at least some of said video content in said rendered color space by decoding said video signal into a set of frames, extracting said color information from only selected extraction frames, and performing interframe interpolation between said extraction frames to yield interpolated frames, said color
30   information then newly derived from said extraction frames and said interpolated frames;

[2] Extracting an average color from the color information from an extraction region in each of the individual frames; [3] Transforming the average color to an unrendered color space; [4] Transforming the average color from the unrendered color space to a second rendered color space so formed as to allow driving the ambient light source; and [5] using the

5   average color to broadcast ambient light from the ambient light source adjacent the extraction region. Steps [1], [2], [3], [4], and [5] can be substantially synchronous with the video signal.

In addition, a method is disclosed for extracting and processing border region video content from a rendered color space to be emulated by an ambient light source, using a colorimetric estimate and employing an interframe interpolation process, comprising: [1]

10   Extracting color information from a video signal that encodes at least some of said video content in said rendered color space by decoding said video signal into a set of frames, extracting said color information from only selected extraction frames, and performing interframe interpolation between said extraction frames to yield interpolated frames, said color information then newly derived from said extraction frames and said interpolated frames; [2]

15   Extracting a colorimetric estimate from the color information from an extraction region in each of the individual frames; [3] Transforming the colorimetric estimate to an unrendered color space; [4] Transforming the colorimetric estimate from the unrendered color space to a second rendered color space so formed as to allow driving the ambient light source; and [5] using the colorimetric estimate to broadcast ambient light (L4) from the ambient light source

20   adjacent the extraction region.

FIG. 1 shows a simple front surface view of a video display showing color information extraction regions and associated broadcasting of ambient light from six ambient light sources according to the invention;

FIG. 2 shows a downward view – part schematic and part cross-sectional – of a

25   room in which ambient light from multiple ambient light sources is produced using the invention;

FIG. 3 shows a system according to the invention to extract color information and effect color space transformations to allow driving an ambient light source;

FIG. 4 shows an equation for calculating average color information from a video

30   extraction region;

FIG. **5** shows a prior art matrix equation to transform rendered primaries **RGB** into unrendered color space **XYZ**;

FIGS. **6** and **7** show matrix equations for mapping video and ambient lighting rendered color spaces, respectively, into unrendered color space;

FIG. **8** shows a solution using known matrix inversion to derive ambient light tristimulus values **R'G'B'** from unrendered color space **XYZ**;

FIGS. **9-11** show prior art derivation of tristimulus primary matrix **M** using a white point method;

FIG. **12** shows a system similar to that shown in FIG. **3**, additionally comprising a gamma correction step for ambient broadcast;

FIG. **13** shows a schematic for a general transformational process used in the invention;

FIG. **14** shows process steps for acquiring transformation matrix coefficients for an ambient light source used by the invention;

FIG. **15** shows process steps for estimated video extraction and ambient light reproduction using the invention;

FIG. **16** shows a schematic of video frame extraction according to the invention;

FIG. **17** shows process steps for abbreviated chrominance assessment according to the invention;

FIG. **18** shows an extraction step as shown in FIGS. **3** and **12**, employing a frame decoder, setting a frame extraction rate and performing an output calculation for driving an ambient light source;

FIGS. **19** and **20** show process steps for color information extraction and processing for the invention.

The following definitions shall be used throughout:

– **Ambient light source** – shall, in the appended claims, include any lighting production circuits or drivers needed to decode a light script code for use thereby.

– **Ambient space** – shall connote any and all material bodies or air or space external to a video display unit.

– **Average color** – shall, in the appended claims, include average characterizations

other than numerical averages, and shall include functional or operator-defined characterizations of video content, including offsets of chromaticities and luminances.

-- **Chrominance** – shall, in the context of driving an ambient light source, denote a mechanical, numerical, or physical way of specifying the color character of light produced,
5 and shall not imply a particular methodology, such as that used in NTSC or PAL television broadcasting.

– **Color information** – shall include either or both of **chrominance** and **luminance**, or functionally equivalent quantities.

-- **Computer** – shall include not only all processors, such as CPU's (Central
10 Processing Units) that employ known architectures, but also any intelligent device that can allow coding, decoding, reading, processing, execution of setting codes or change codes, such as digital optical devices, or analog electrical circuits that perform the same functions.

– **Controlled operating parameter** – shall denote a parameter encoded as a representation of a physical quantity or physical variable, such as a luminance, a chrominance,
15 or a light character index such as a delivery angle or a goniophotometric index.

-- **Goniochromatic** – shall refer to the quality of giving different color or chromaticity as a function of viewing angle or angle of observation, such as produced by iridescence.

– **Goniophotometric** – shall refer to the quality of giving different light intensity, transmission and/or color as a function of viewing angle or angle of observation, such as found
20 in pearlescent, sparkling or retroreflective phenomena.

– **Interpolate** – shall include linear or mathematical interpolation between two sets of values, as well as functional prescriptions for setting values between two known sets of values.

– **Light character** – shall mean, in the broad sense, any specification of the nature of light such as produced by an ambient light source, including all descriptors other than
25 luminance and chrominance, such as the degree of light transmission or reflection; or any specification of goniophotometric qualities, including the degree to which colors, sparkles, or other known phenomena are produced as a function of viewing angles when observing an ambient light source; a light output direction, including directionality as afforded by specifying a Poynting or other propagation vector; or specification of angular distribution of
30 light, such as solid angles or solid angle distribution functions. It can also include a coordinate

or coordinates to specify locations on an ambient light source, such as element pixels or lamp locations.

— **Luminance** — shall denote any parameter or measure of brightness, intensity, or equivalent measure, and shall not imply a particular method of light generation or

5   measurement, or psycho-biological interpretation.

— **Rendered color space** — shall denote an image or color space captured from a sensor, or specific to a source or display device, which is device and image-specific. Most RGB color spaces are rendered image spaces, including the video spaces used to drive video display **D**. In the appended claims, both the color spaces specific to the video display and the

10   ambient light source **88** are rendered color spaces.

— **Transforming color information to an unrendered color space** — in the appended claims shall comprise either direct transformation to the unrendered color space, or use or benefit derived from using inversion of a tristimulus primary matrix obtained by transforming to the unrendered color space (e.g., $(M_2)^{-1}$ as shown in FIG. 8).

15   — **Unrendered color space** — shall denote a standard or non-device-specific color space, such as those describing original image colorimetry using standard CIE XYZ; ISO RGB, such as defined in ISO 17321 standards; Photo YCC; and the CIE LAB color space.

— **Video** — shall denote any visual or light producing device, whether an active device requiring energy for light production, or any transmissive medium which conveys image

20   information, such as a window in an office building, or an optical guide where image information is derived remotely.

— **Video signal** — shall denote the signal or information delivered for controlling a video display unit, including any audio portion thereof. It is therefore contemplated that video content analysis includes possible audio content analysis for the audio portion. Generally, a

25   video signal can comprise any type of signal, such as radio frequency signals using any number of known modulation techniques; electrical signals, including analog and quanitized analog waveforms; digital (electrical) signals, such as those using pulse-width modulation, pulse-number modulation, pulse-position modulation, PCM (pulse code modulation) and pulse amplitude modulation; or other signals such as acoustic signals, audio signals, and optical

30   signals, all of which can use digital techniques. Data that is merely sequentially placed

among or with other information, such as in computer-based applications, can be used as well.

Ambient light derived from video content according to the invention is formed to allow, if desired, a high degree of fidelity to the chromaticity of original video scene light, while maintaining a high degree of specificity of degrees of freedom for ambient lighting with

5   a low required computational burden. This allows ambient light sources with small color gamuts and reduced luminance spaces to emulate video scene light from more advanced light sources with relatively large colors gamuts and luminance response curves. Possible light sources for ambient lighting can include any number of known lighting devices, including LEDs (Light Emitting Diodes) and related semiconductor radiators; electroluminescent

10   devices including non-semiconductor types; incandescent lamps, including modified types using halogens or advanced chemistries; ion discharge lamps, including fluorescent and neon lamps; lasers; light sources that are modulated, such as by use of LCDs (liquid crystal displays) or other light modulators; photoluminescent emitters, or any number of known controllable light sources, including arrays that functionally resemble displays.

15   Now referring to FIG. 1, a simple front surface view of a video display **D** according to the invention is shown illustratively. Display **D** can be any of a number of known devices which decode video content from a rendered color space, such as an NTSC, PAL or SECAM broadcast standard, or an rendered RGB space, such as Adobe RGB. Display **D** comprises color information extraction regions **R1, R2, R3, R4, R5,** and **R6** whose borders are arbitrarily

20   pre-defined and which are to be characterized for the purpose of producing characteristic ambient light **A8**, such as via back-mounted controllable ambient lighting units (not shown) which produce and broadcast ambient light **L1, L2, L3, L4, L5,** and **L6** as shown, such as by partial light spillage to a wall (not shown) on which display **D** is mounted. Alternatively, a display frame **Df** as shown can itself also comprise ambient lighting units which display light

25   in a similar manner, including outward toward a viewer (not shown). If desired, each color information extraction region **R1 - R6** can influence ambient light adjacent itself. For example, color information extraction region **R4** can influence ambient light **L4** as shown.

Now referring to FIG. 2, a downward view — part schematic and part cross-sectional — is shown of a room or ambient space **AO** in which ambient light from multiple ambient light

30   sources is produced using the invention. In ambient space **AO** is arranged seating and tables 7

as shown which are arrayed to allow viewing of video display **D**. In ambient space **AO** are
also arrayed a plurality of ambient light units which are optionally controlled using the instant
invention, including light speakers **1 - 4** as shown, a sublight **SL** under a sofa or seat as shown,
as well as a set of special emulative ambient light units arrayed about display **D**, namely center
5   lights that produce ambient light **Lx** like that shown in FIG. 1. Each of these ambient light
units can emit ambient light **A8**, shown as shading in the figure.

In cooperation with the instant invention, one can produce ambient light from these
ambient light units with colors or chromaticities derived from, but not actually broadcast by
video display **D**. This allows exploiting characteristics of the human eye and visual system. It
10   should be noted that the luminosity function of the human visual system, which gives
detection sensitivity for various visible wavelengths, changes as a function of light levels.

For example, scotopic or night vision relying on rods tends to be more sensitive to
blues and greens. Photopic vision using cones is better suited to detect longer wavelength
light such as reds and yellows. In a darkened home theatre environment, such changes in
15   relative luminosity of different colors as a function of light level can be counteracted
somewhat by modulating or changing color delivered to the video user in ambient space. This
can be done by subtracting light from ambient light units such as light speakers 1 - 4 using a
light modulator (not shown) or by use of an added component in the light speakers, namely a
photoluminescent emitter to further modify light before ambient release. The
20   photoluminescent emitter performs a color transformation by absorbing or undergoing
excitation from incoming light from light source and then re-emitting that light in higher
desired wavelengths. This excitation and re-emission by a photoluminescent emitter, such as
a fluorescent pigment, can allow rendering of new colors not originally present in the original
video image or light source, and perhaps also not in the range of colors or color gamut
25   inherent to the operation of the display **D**. This can be helpful for when the desired luminance
of ambient light **Lx** is low, such as during very dark scenes, and the desired level of perception
is higher than that normally achieved without light modification.

The production of new colors can provide new and interesting visual effects. The
illustrative example can be the production of orange light, such as what is termed hunter's
30   orange, for which available fluorescent pigments are well known (see ref[2]). The example

given involves a fluorescent color, as opposed to the general phenomenon of fluorescence and related phenomena. Using a fluorescent orange or other fluorescent dye species can be particularly useful for low light conditions, where a boost in reds and oranges can counteract the decreased sensitivity of scotopic vision for long wavelengths.

5   Fluorescent dyes that can be used in ambient light units can include known dyes in dye classes such as Perylenes, Naphthalimides, Coumarins, Thioxanthenes, Anthraquinones, Thioindigoids, and proprietary dye classes such as those manufactured by the Day-Glo Color Corporation, Cleveland, Ohio, USA. Colors available include Apache Yellow, Tigris Yellow, Savannah Yellow, Pocono Yellow, Mohawk Yellow, Potomac Yellow, Marigold Orange,
10   Ottawa Red, Volga Red, Salmon Pink, and Columbia Blue. These dye classes can be incorporated into resins, such as PS, PET, and ABS using known processes.

         Fluorescent dyes and materials have enhanced visual effects because they can be engineered to be considerably brighter than nonfluorescent materials of the same chromaticity. So-called durability problems of traditional organic pigments used to generate fluorescent
15   colors have largely been solved in the last two decades, as technological advances have resulted in the development of durable fluorescent pigments that maintain their vivid coloration for 7-10 years under exposure to the sun. These pigments are therefore almost indestructible in a home theatre environment where UV ray entry is minimal.

         Alternatively, fluorescent photopigments can be used, and they work simply by
20   absorbing short wavelength light, and re-emitting this light as a longer wavelength such as red or orange. Technologically advanced inorganic pigments are now readily available that undergo excitation using visible light, such as blues and violets, e.g., 400-440 nm light.

         Goniophotometric and goniochromatic effects can similarly be deployed to produce different light colors, intensity, and character as a function of viewing angles. To realize this
25   effect, ambient light units 1 - 4 and SL and Lx can use known goniophotometric elements (not shown), alone, or in combination, such as metallic and pearlescent transmissive colorants; iridescent materials using well-known diffractive or thin-film interference effects, e.g., using fish scale essence; thin flakes of guanine; or 2-aminohypoxanthine with preservative. Diffusers using finely ground mica or other substances can be used, such as pearlescent
30   materials made from oxide layers, bornite or peacock ore; metal flakes, glass flakes, or plastic

flakes; particulate matter; oil; ground glass, and ground plastics.

Now referring FIG. 3, a system according to the invention to extract color information and effect color space transformations to allow driving an ambient light source is shown. As a first step, color information is extracted from a video signal **AVS** using known
5   techniques.

Video signal **AVS** can comprise known digital data frames or packets like those used for MPEG encoding, audio PCM encoding, etc. One can use known encoding schemes for data packets such as program streams with variable length data packets, or transport streams which divide data packets evenly, or other schemes such single program transport
10   streams. Alternately, the functional steps or blocks given in this disclosure can be emulated using computer code and other communications standards, including asynchronous protocols.

As a general example, the video signal **AVS** as shown can undergo video content analysis **CA** as shown, using known methods to record and transfer selected content to and from a hard disk **HD** as shown, possibly using a library of content types or other information
15   stored in a memory **MEM** as shown. This can allow independent, parallel, direct, delayed, continuous, periodic, or aperiodic transfer of selected video content. From this video content one can perform feature extraction **FE** as shown, such as deriving color information. This color information is still encoded in a rendered color space, and is then transformed to an unrendered color space, such as CIE XYZ using a RUR Mapping Transformation Circuit **10** as
20   shown. RUR herein stands for the desired transformation type, namely, rendered-unrendered-rendered, and thus RUR Mapping Transformation Circuit **10** also further transforms the color information to a second rendered color space so formed as to allow driving said ambient light source or sources **88** as shown.

RUR Mapping Transformation Circuit **10** can be functionally contained in a
25   computer system which uses software to perform the same functions, but in the case of decoding packetized information sent by a data transmission protocol, there could be memory (not shown) in the circuit **10** which contains, or is updated to contain, information that correlates to or provides video rendered color space coefficients and the like. This newly created second rendered color space is appropriate and desired to drive ambient light source **88**
30   (such as shown in FIGS. **1** and **2**), and is fed using known encoding to ambient lighting

production circuit **18** as shown. Ambient lighting production circuit **18** takes the second rendered color space information from RUR Mapping Transformation Circuit **10** and then accounts for any input from any user interface and any resultant preferences memory (shown together as **U2**) to develop actual ambient light output control parameters (such as applied

5   voltages) after possibly consulting an ambient lighting (second rendered) color space lookup table **LUT** as shown. The ambient light output control parameters generated by ambient lighting production circuit **18** are fed as shown to lamp interface drivers **D88** to directly control or feed ambient light source **88** as shown, which can comprise individual ambient light units **1 - N**, such as previously cited ambient light speakers **1 - 4** or ambient center lights **Lx** as

10   shown in FIGS. **1** and **2**.

        To reduce the computational burden, the color information removed from video signal **AVS** can be abbreviated or limited. Now referring to FIG.4, an equation for calculating average color information from a video extraction region is shown. It is contemplated, as mentioned below (see FIG. 18), that the video content in video signal **AVS** will comprise a

15   series of time sequenced video frames, but this is not required. For each video frame or equivalent temporal block, one can extract average or other color information from each extraction region (e.g., **R4**). Each extraction region can be set to have a certain size, such as 100 by 376 pixels. Assuming, for example, a frame rate of 25 frame/sec, the resultant gross data for extraction regions **R1 - R6** before extracting an average (assuming only one byte

20   needed to specify 8 bit color) would be 6 x 100 x 376 x 25 or 5.64 million bytes/sec for each video RGB tristimulus primary. This data stream is very large and would be difficult to handle at RUR Mapping Transformation Circuit **10**, so extraction of an average color for each extraction region **R1 - R6** can be effected during Feature Extraction **FE**. Specifically, as shown one can sum the RGB color channel value (e.g., R_{ij}) for each pixel in each extraction

25   region of m x n pixels, and divide by the number of pixels m x n to arrive at an average for each RGB primary, e.g., R_{avg} for red, as shown. Thus repeating this summation for each RGB color channel, the average for each extraction region would be a triplet $R_{AVG} = |R_{avg}, G_{avg}, B_{avg}|$. The same procedure is repeated for all extraction regions

        R1 - R6 and for each RGB color channel. The number and size of extractive regions can depart from that shown, and be as desired.

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The next step of performing color mapping transformations by RUR Mapping Transformation Circuit **10** can be illustratively shown and expressed using known tristimulus primary matrices, such as shown in FIG. **5**, where a rendered tristimulus color space with vectors **R, G,** and **B** is transformed using the tristimulus primary matrix **M** with elements such

5   as $X_{r,max}$, $Y_{r,max}$, $Z_{r,max}$ where $X_{r,max}$ is tristimulus value of the R primary at maximum output.

The transformation from a rendered color space to unrendered, device-independent space can be image and/or device specific — known linearization, pixel reconstruction (if necessary), and white point selection steps can be effected, followed by a matrix conversion. In this case, we simply elect to adopt the rendered video output space as a starting point for

10   transformation to an unrendered color space colorimetry. Unrendered images need to go through additional transforms to make them viewable or printable, and the RUR transformation involves a transform to a second rendered color space.

As a first possible step, FIGS. **6** and **7** show matrix equations for mapping the video rendered color space, expressed by primaries **R, G,** and **B** and ambient lighting rendered color

15   space, expressed by primaries **R', G',** and **B'** respectively, into unrendered color space **X, Y,** and **Z** as shown, where tristimulus primary matrix M_1 transforms video **RGB** into unrendered **XYZ,** and tristimulus primary matrix M_2 transforms ambient light source **R'G'B'** into unrendered **XYZ** color space as shown. Equating both rendered color spaces **RGB** and **R'G'B'** as shown in FIG. **8** allows matrix transformations of primaries **RGB** and **R'G'B'** of

20   the rendered (video) color space and second rendered (ambient) color space to said unrendered color space (the RUR Mapping Transformation) using the first and second tristimulus primary matrices (M_1, M_2);and deriving a transformation of color information into the second rendered color space (**R'G'B'**) by matrix multiplication of the **RGB** primaries of the rendered video color space, the first tristimulus matrix M_1, and the inverse of the second tristimulus matrix

25    $(M_2)^{-1}$. While the tristimulus primary matrix for known display devices is readily available, that for the ambient light source can be determined using a known white point method by those of ordinary skill in the art.

Now referring to FIGS. **9-11**, prior art derivation of a generalized tristimulus primary matrix **M** using a white point method is shown. In FIG. **9**, quantities like S_rX_r

30   represents the tristimulus value of each (ambient light source) primary at maximum output,

with S_r representing a white point amplitude, and X_r representing the chromaticities of primary light produced by the (ambient) light source. Using the white point method, the matrix equation equating S_r with a vector of the white point reference values using a known inverse of a light source chromaticity matrix as shown. FIG. 11 is an algebraic manipulation

5   to remind that the white point reference values such as X_w are a product of the white point amplitudes or luminances and the light source chromaticities. Throughout, the tristimulus value X is set equal to chromaticity x; tristimulus value Y is set equal to chromaticity y; and tristimulus value Z is defined to be set equal to $1-(x+y)$. As is known, the color primaries and reference white color components for the second rendered ambient light source color

10   space can be acquired using known techniques, such as by using a color spectrometer.

       Similar quantities for the first rendered video color space can be found. For example, it is known that contemporary studio monitors have slightly different standards in North America, Europe, and Japan. However, international agreement has been obtained on primaries for high-definition television (HDTV), and these primaries are closely representative

15   of contemporary monitors in studio video, computing, and computer

       graphics. The standard is formally denoted ITU-R Recommendation BT.709, which contains the required parameters, where the relevant tristimulus primary matrix (M) for RGB is:

       0.640 0.300 0.150   Matrix M for ITU-R BT.709

20   0.330 0.600 0.060

       0.030 0.100 0.790

       and the white point values are known as well.

       Now referring to FIG. 12, a system similar to that shown in FIG. 3 is shown, additionally comprising a gamma correction step 55 after feature extraction step FE as shown

25   for ambient broadcast. Alternatively, gamma correction step 55 can be performed between the steps performed by RUR Mapping Transformation Circuit 10 and Ambient Lighting Production Circuit 18. Optimum gamma values for LED ambient light sources has been found to be 1.8, so a negative gamma correction to counteract a typical video color space gamma of 2.5 can be effected with the exact gamma value found using known mathematics.

30   Generally, RUR Mapping Transformation Circuit 10, which can be a functional

block effected via any suitable known software platform, performs a general RUR transformation as shown in FIG. **13**, where a schematic as shown takes video signal **AVS** comprising a **Rendered Color Space** such as Video RGB, and transforms it to an unrendered color space such as CIE XYZ; then to a **Second Rendered Color Space** (Ambient Light Source RGB). After this RUR transformation, ambient light sources **88** can be driven, aside from signal processing, as shown.

FIG. **14** shows process steps for acquiring transformation matrix coefficients for an ambient light source used by the invention, where the steps include, as shown, Driving the ambient light unit(s); and Checking Output Linearity as known in the art. If the ambient light source primaries are stable, (shown on left fork, **Stable Primaries**), one can Acquire Transformation Matrix Coefficients Using a Color Spectrometer; whereas if the ambient light source primaries are not stable, (shown on right fork, **Unstable Primaries**), one can reset the previously given gamma correction (shown, **Reset Gamma Curve**).

In general, it is desirable, but not necessary to extract color information from every pixel in extraction regions such as **R4**, and instead, if desired, polling of selected pixels can allow a faster estimation of average color, or a faster creation of a extraction region color characterization, to take place. FIG. **15** shows process steps for estimated video extraction and ambient light reproduction using the invention, where steps include [1] **Prepare Colorimetric Estimate of Video Reproduction (From Rendered Color Space, e.g., Video RGB)**; [2] **Transform to Unrendered Color Space**; and [3] **Transform Colorimetric Estimate for Ambient Reproduction (Second Rendered Color Space, e.g., LED RGB)**.

It should be noted that it has been discovered that the required data bitstream required to support extraction and processing of video content from video frames (see FIG. **18** below) can be reduced according to the invention by judicious subsampling of video frames. Now referring to FIG. **16**, a schematic of video frame extraction according to the invention is shown. A series individual successive of video frames **F**, namely frames **F₁, F₂, F₃** and so on, such as individual interlaced or non-interlaced video frames specified by the NTSC, PAL, or SECAM standards, is shown. By doing content analysis and/or feature extraction – such as extracting color information – from selected successive frames, such as frames **F₁** and **F_N**, one can reduce data load or overhead while maintaining acceptable ambient light source

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responsiveness, realism, and fidelity. It has been found that $N = 10$ gives good results, namely, subsampling 1 frame out of 10 successive frames can work. This provides a refresh period P between frame extractions of low processing overhead during which an interframe interpolation process can provide adequate approximation of the time development of

5   chrominance changes in display D. Selected frames F_1 and F_N are extracted as shown (EXTRACT) and intermediate interpolated values for chrominance parameters shown as G_2, G_3, G_4 provide the necessary color information to inform the previously cited driving process for ambient light source 88 . This obviates the need to simply freeze or maintain the same color information throughout frames 2 through N-1. The interpolated values can be linearly

10   determined, such as where the total chrominance difference between extracted frames F_1 and F_N is spread over the interpolated frames G. Alternatively, a function can spread the chrominance difference between extracted frames F_1 and F_N in any other manner, such as to suit higher order approximation of the time development of the color information extracted.

FIG. 17 shows process steps for abbreviated chrominance assessment according to

15   the invention. Higher order analysis of frame extractions can larger refresh periods P and larger N than would otherwise be possible. During frame extraction, or during a provisional polling of selected pixels in extraction regions R_x, one can conduct an abbreviated chrominance assessment as shown that will either result in a delay in the next frame extraction, as shown on the left, or initiating a full frame extraction, as shown on the right. In

20   either case, interpolation proceeds, with a delayed next frame extraction resulting in frozen, or incremented chrominance values being used. This can provide even more economical operation in terms of bitstream or bandwidth overhead.

FIG. 18 shows the top of FIGS. 3 and 12, where an alternative extraction step is shown whereby a frame decoder FD is used, allowing for regional information from extraction

25   regions (e.g, $R1$) is extracted at step 33 as shown. A further process or component step 35 includes assessing a chrominance difference, and using that information to set a video frame extraction rate, as indicated. A next process step of performing output calculations 00, such as the averaging of FIG. 4, is performed as shown, prior to data transfer to Ambient Lighting and Production Circuit 18 previously shown.

30   As shown in FIG. 19, general process steps for color information extraction and

processing for the invention include acquiring an video signal AVS; extracting regional (color) information from selected video frames (such as previously cited F_1 and F_N); interpolating between the selected video frames; an RUR Mapping Transformation; optional gamma correction; and using this information to drive an ambient light source (88). As shown in FIG.

5   20, two additional process steps can be inserted after the regional extraction of information from selected frames: one can perform an assessment of the chrominance difference between selected frames F_1 and F_N, and depending on a preset criterion, one can set a new frame extraction rate as indicated. Thus, if a chrominance difference between successive frames F_1 and F_N is large, or increasing rapidly (e.g, a large first derivative), or satisfies some other

10   criterion, such as based on chrominance difference history, one can then increase the frame extraction rate, thus decreasing refresh period P. If, however, a chrominance difference between successive frames F_1 and F_N is small, and is stable or is not increasing rapidly (e.g, a low or zero absolute first derivative), or satisfies some other criterion, such as based on chrominance difference history, one can then save on the required data bitstream required and

15   decrease the frame extraction rate, thus increasing refresh period P.

Generally, ambient light source 88 can embody various diffuser effects to produce light mixing, as well as translucence or other phenomena, such as by use of lamp structures having a frosted or glazed surface; ribbed glass or plastic; or apertured structures, such as by using metal structures surrounding an individual light source. To provide interesting effects,

20   any number of known diffusing or scattering materials or phenomena can be used, including that obtain by exploiting scattering from small suspended particles; clouded plastics or resins, preparations using colloids, emulsions, or globules 1-5 :m or less, such as less than 1 :m, including long-life organic mixtures; gels; and sols, the production and fabrication of which is known by those skilled in the art. Scattering phenomena can be engineered to include

25   Rayleigh scattering for visible wavelengths, such as for blue production for blue enhancement of ambient light. The colors produced can be defined regionally, such as an overall bluish tint in certain areas or regional tints, such as a blue light-producing top section (ambient light L_1 or L_2).

Ambient lamps can also be fitted with a goniophotometric element, such as a

cylindrical prism or lens which can be formed within, integral to, or inserted within a lamp structure. This can allow special effects where the character of the light produced changes as a function of the position of the viewer. Other optical shapes and forms can be used, including rectangular, triangular or irregularly-shaped prisms or shapes, and they can be placed upon or

5   integral to an ambient light unit or units. The result is that rather than yielding an isotropic output, the effect gained can be infinitely varied, e.g., bands of interesting light cast on surrounding walls, objects, and surfaces placed about an ambient light source, making a sort of light show in a darkened room as the scene elements, color, and intensity change on a video display unit. The effect can be a theatrical ambient lighting element which changes light

10   character very sensitively as a function of viewer position – such as viewing bluish sparkles, then red light – when one is getting up from a chair or shifting viewing position when watching a home theatre. The number and type of goniophotometric elements that can be used is nearly unlimited, including pieces of plastic, glass, and the optical effects produced from scoring and mildly destructive fabrication techniques. Ambient lamps can be made to be   .

15   unique, and even interchangeable, for different theatrical effects. And these effects can be modulatable, such as by changing the amount of light allowed to pass through a goniophotometric element, or by illuminating different portions (e.g., using sublamps or groups of LEDs) of an ambient light unit.

        In this way, ambient light produced at **L3** to emulate extraction region **R3** as shown

20   in FIG. **1** can have a chromaticity that provides a perceptual extension of a phenomenon in that region, such as the moving fish as shown. This can multiply the visual experience and provide hues which are appropriate and not garish or unduly mismatched.

        Video signal **AVS** can of course be a digital datastream and contain synchronization bits and concatenation bits; parity bits; error codes; interleaving; special modulation; burst

25   headers, and desired metadata such as a description of the ambient lighting effect (e.g., "lightning storm"; "sunrise"; etc.) and those skilled in the art will realize that functional steps given here are merely illustrative and do not include, for clarity, conventional steps or data.

        The User Interface & Preferences Memory as shown in FIGS. **3** and **12** can be used to change preferences regarding the system behavior, such as changing the degree of color

30   fidelity to the video content of video display **D** desired; changing flamboyance, including the

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extent to which any fluorescent colors or out-of-gamut colors are broadcast into ambient space, or how quickly or greatly responsive to changes in video content the ambient light is, such as by exaggerating the intensity or other quality of changes in the light script command content. This can include advanced content analysis which can make subdued tones for movies or content of certain character. Video content containing many dark scenes in content can influence behavior of the ambient light source **88**, causing a dimming of broadcast ambient light, while flamboyant or bright tones can be used for certain other content, like lots of flesh tone or bright scenes (a sunny beach, a tiger on savannah, etc.).

The description is given here to enable those of ordinary skill in the art to practice the invention. Many configurations are possible using the instant teachings, and the configurations and arrangements given here are only illustrative. In practice, the methods taught and claimed might appear as part of a larger system, such as an entertainment center or home theatre center.

It is well known that for the functions and calculations illustratively taught here can be functionally reproduced or emulated using software or machine code, and those of ordinary skill in the art will be able to use these teachings regardless of the way that the encoding and decoding taught here is managed.

Those with ordinary skill in the art will, based on these teachings, be able to modify the apparatus and methods taught and claimed here and thus, for example, re-arrange steps or data structures to suit specific applications, and creating systems that may bear little resemblance to those chosen for illustrative purposes here.

The invention as disclosed using the above examples may be practiced using only some of the features mentioned above. Also, nothing as taught and claimed here shall preclude addition of other structures or functional elements.

Obviously, many modifications and variations of the present invention are possible in light of the above teaching. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described or suggested here.